Does Classical Physics Double Every 15-20 Years, or, What Would It Mean for Science to Grow Exponentially?

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Abstract

I seek to evaluate Edward O. Wilson's claim, in his *Letters to a Young Scientist*, that "scientific knowledge doubles every 15-20 years," and that science grows exponentially like technology or technological growth. Wilson's claim is sometimes endorsed by contemporary scientists and technologists.

There are at least two ways of evaluating Wilson's claim, quantitatively, and qualitatively and quantitatively: 1) Historians and sociologists of science have sought to show that while scientific publications in particular fields or sub-fields may grow exponentially in their early phases, the number of scientific publications does not grow exponentially over the long term; 2) the established knowledge of physics textbooks does not double every 15-20 years; the established knowledge of classical physics does not double every 15-20 years; more generally, the established knowledge of science does not double every 15-20 years.

Instead of growing exponentially, I suggest that science usually "lags" behind technology and technological growth; however, there are exceptional cases of scientific discoveries, scientific theory, and scientific paradigms 'jumping' or 'flying' ahead of contemporary technology.

Does Classical Physics Double Every 15-20 Years, or, What Would It Mean for Science to Grow Exponentially?

1. **In this paper, I seek to evaluate Edward O. Wilson's claim, in his book *Letters to a Young Scientist*, that "scientific knowledge doubles every 15-20 years," and that science grows exponentially like technology or technological growth.**

At least since William Ogburn's work on the subject earlier in the 20th century, it has been recognized that technology or material culture potentially grows exponentially in the evolution of human societies.

Wilson, however, claims that not only is technological growth exponential, but that scientific growth is exponential as well: "High technology runs at a comparable pace alongside . . . science." Wilson also claims that exponential growth in science "will continue through most of the 21st century," though at some point scientific growth will plateau or "level off."

In the journal *Nature*, scientist Alexander Szalay and former Microsoft scientist Jim Gray claim that, "the amount of scientific data is doubling every year," and that, "as data volumes grow, it is increasingly arduous to extract knowledge." Alexander Szalay and Jim gray comment that, because of the growth in the amount of data, "scientists must labour to organize . . . and reduce the data . . . producing smaller data sets that eventually lead to the big picture."

It is an interesting question of how to evaluate the nature of technological growth. From the perspective of William Ogburn and others, the macroscopic perspective of the evolution of human societies in the evolution of the human species, technological growth is exponential or potentially exponential.

However, from a more "fine-grained" perspective, technologists sometimes comment that different technologies grow at faster rates than others. G.E.

Moore, co-founder of the Intel Corporation, sought to establish "Moore's Law," that computer processing power doubles every two years (Moore initially suggested that the processing power of computer chips doubled every 18 months, and revised his estimation to every two years). "Moore's Law" is commonly viewed as a model for the suggestion that science and technology grow exponentially. However, computer scientists T. Lewis and G. Denning comment that, clearly, not all technologies grow exponentially: "Moore's Law. . . is not available for every technology. We might wish for automobiles that travel 1,600 miles on a gallon of gasoline—approximately six doublings (2^6) better than today's most efficient automobiles." The following generations of automobiles would be expected to get 3,200 miles per gallon, 6,400 miles per gallon, etc.

Thus, gasoline or diesel fuel vehicles do not demonstrate exponential growth in their horsepower, torque, or fuel efficiency over the longer term: In the event that gasoline or diesel fuel automobiles doubled in their horsepower every generation, the vehicles would travel faster than planes, rockets, or NASA spacecraft. In the short term, in their early stages, new technologies may grow exponentially, and then plateau or level off in their growth, power, of efficiency.

However, from Ogburn's perspective, over the longer term, new technologies may emerge that replace or provide alternatives to existing technologies, that may give the appearance of exponential growth: The electric vehicles of Tesla Motors, for example, in effect travel more than 1600 miles per gallon; however, in terms of their everyday usability, Tesla Motors cars may travel approximately 200-250 miles before requiring re-charging, and the new generation of Tesla Motors vehicles are supposed to be able to travel 400 miles before requiring re-charging.

In the area of scientific publications, sometimes treated as a measure of scientific productivity, it has been alleged that scientific growth is exponential. However, this may only be the case in the early stages of scientific growth in particular branches of science or sub-branches or sub-fields of science. In 2012, the number of peer-reviewed scholarly journal publications, including science journals, was 28,100 (cited in Rouse 2016). If the growth rate of scientific journals was exponential, the number of scientific journals in 2012 might have been in the hundreds of thousands or millions, depending on the start date at which the doubling rate was

expected to begin. Instead, as suggested, early exponential growth in scientific publications is a short-term process limited to the early stages of growth of new branches or sub-branches of science, or when a revolutionary advance or invention in an established branch or sub-branch attracts short-term exponential growth before returning to the earlier rate of growth (i.e., returning to the "equilibrium" after the "punctuation"), leveling off to a lower rate of growth compared to the short-term exponential growth, reaching a plateau, or possibly contracting somewhat as a sub-branch of science compared to other branches or sub-branches.

Lewis and Denning discuss Moore's Law, and how the processing power of computer chips has doubled approximately every two years at least since the 1950s; however, has the efficiency and usability of commercially available computers doubled every two years? Since the development of commercially available personal computers in the 1980s, has the usability and efficiency of personal computers doubled every 2 years, or even with every generation of personal computers? Clearly, the answer is no. Instead, the introduction of Graphical User Interface (GUI) software by Apple and Microsoft increased the usability and efficiency more than the doubling of the processing power of computer chips; advances in the software of Graphical User Interfaces, such as Microsoft PowerPoint and Office Applications, and graphical user interface software for Apple Iphones, Ipads, and other computers and devices have increased the usability of commercially available computers more than the doubling of the processing power of computer chips. Thus, exponential growth may sometimes be a "mirage," and other kinds or types of advances in technology or science may be more important or fundamental for efficiency, productivity, usability, or societal, technological, or scientific growth (as in advances in software versus the doubling of computer chip processing power ever 2 years, or particular advances or inventions in science or technology versus the sheer growth in the number of scientific articles or scientific journals in a branch or sub-field).

2. **Edward Wilson is a brilliant scientist, and his book has numerous forceful statements and advice for young scientists. He states that, "ideas in science emerge when some part of the world is studied for its own sake." Wilson also evaluates and criticizes theoretical models in the biological sciences: "The annals of theoretical biology are clogged with mathematical models that either can be safely ignored,**

> or, when tested, fail." Wilson consistently advocates that scientists test their ideas and theories against empirical reality.

Wilson also encourages scientists to take advantage of the freedom of expression made available by the internet, a degree of freedom of expression he views as consonant with science, scientific values, and scientific progress: "The internet and all other accoutrements of digital technology have rendered communication global and instant. Soon all published knowledge in the sciences and the humanities will be available in a few keystrokes . . . science and technology hide . . . no secrets."

In this response, I seek to evaluate Edward Wilson's claim that science grows exponentially like technology and technological growth. There are at least two ways of evaluating Wilson's claim, quantitatively, and qualitatively and quantitatively: 1) Historians and sociologists of science have sought to show that while scientific publications in particular fields or sub-fields may grow exponentially in their early phases, the number of scientific publications does not grow exponentially over the long term; 2) the established knowledge of classical physics does not double every 15-20 years, and, more generally, the established knowledge of science does not double every 15-20 years.

It is possible to ask, what would it mean if the established knowledge of classical physics, including all of the branches and subfields of classical physics, were to double every 15-20 years? What would textbooks in classical physics and modern physics be like if their knowledge doubled every 15-20 years? Did the knowledge of your physics textbook of this year, including all of the branches and subfields of classical physics and modern physics, double from the physics textbook you had 15-20 years ago? Clearly the answer is no!

The established knowledge of classical physics, the established knowledge of physics from early modern Europe through the end of the 19th century, does not double every 15-20 years; moreover, the established knowledge of post-classical 20th century physics and contemporary physics does not double every 15-20 years. The established knowledge of physics doubling every 15-20 years is not possible.

(This criticism also may be relevant to the interaction and intersection of science, ideas, and the business world in the “information age.” Businessmen and businesses have used Thomas Kuhn's *Structure of Scientific Revolutions* and his concept of "paradigms" to think about different frameworks for understanding strategies of success and performance in the business world. This paper in effect puts Thomas Kuhn's famous ideas about the nature of change and innovation in science in relation to fundamental patterns in human social evolution: The nature of exponential or potential exponential growth in technology is not identical or even nearly identical to cultural growth in science; moreover, science, as a form of symbolic culture, usually 'lags' behind incessant or near incessant technological change and growth; however, there are exceptional cases of scientific theory and scientific discoveries 'jumping' for 'flying ahead’ of contemporary technology. In the business world, the analogy to exceptional cases of scientific theory and scientific discoveries that might 'jump' or 'fly ahead’ of contemporary technology is entrepreneurialism. That is, entrepreneurs sometimes envision or found businesses that are ahead of contemporary technology, and result in pushing contemporary technology in new directions that were not previously sustained by market conditions or established technology; an exemplar would be Steven Jobs and Bill Gates seeking to establish a market for personal computers with software usable by the public when the computer industry was still dominated by IBM and the consumer market for computers was still dominated by relatively large businesses).

3. **Contra Thomas Kuhn, science may be classifiable as a kind of culture under the frameworks of Alfred Louis Kroeber and William Ogburn: Thus, science may be expected to usually “lag” behind incessant or near incessant technological growth; however, Kroeber and Kuhn recognize that in science and cultural phenomena more generally, there are sometimes advances in science and culture that “jump,” “leap,” or “fly” ahead of the social patterns of their contemporaries, including the technological growth of their contemporaries.**

William Ogburn was the first scientist to claim that cultural growth is exponential or potentially exponential over the generations of human evolution: that early simple societies for most of human evolution, from archaic *Homo Sapiens* approximately 500,000 years ago to 10,000 years ago had relatively small amounts of culture and technology, and slow rates

of cultural accretion, until the neolithic revolution of established settlements and the emergence of writing systems 10,000 years ago; since the neolithic revolution, post-neolithic societies have had much faster rates of cultural and technological growth compared to pre-neolithic societies, as the base of culture, including a larger base of combinations of existing technologies and inventions, have increased. Societies that have participated in the industrial revolution, have had much faster rates of technological and cultural growth than pre-industrial societies; thus, Ogburn suggested that material cultural growth or technological growth have been exponential from the earliest simple societies to contemporary post-industrial societies; thus, while Darwin sought to establish the gradual nature of the evolution of biological species, Ogburn (called a "Darwin of the social sciences") showed that material cultural growth or technological growth is exponential or nearly exponential in the evolution of human societies from archaic *Homo Sapiens* to most contemporary societies around the world; from a more microscopic or "fine-grained" perspective, the development and success of different patterns in symbolic culture may facilitate or play a role in technological invention and growth ("hardware"), and the diffusion and spread of material culture or technology. In what languages, mathematical systems, or symbolic systems ("software") do individuals or groups contribute potential scientific and technological revolutions? For Copernicus, Galileo, and Newton, exposure or fluency in Latin, Greek, Euclidean geometry, and Arabic numerals may have been cultural prerequisites for their scientific revolutions, and they may have been cultural prerequisites for technological advances and revolutions by their contemporaries (as the graphical user interface and contemporary computer software may be prerequisites that facilitate contemporary scientific and technological advances; in the medieval period, Europe and the West were technologically behind the Arab and Muslim worlds, and also China, before Fibonacci's revolution in cultural diffusion simplifying and spreading Arabic numerals and the decimal system to Europe and the West). From Ogburn's perspective, the greater political diversity and linguistic diversity of Europe contributed to the greater cultural diffusion of ideas and technologies compared to the early modern Muslim world or China, once Europe had reached a level of development that it could compete with the Muslim world and China. From the standpoint of human evolution, the invention of new technologies that may have exponential rates of growth, like increasing computing power described by "Moore's Law," are special cases of Ogburn's Principle. There are debates in the

literature as to whether some sets of technologies, and also societies themselves, may plateau in technological development and growth. However, brief technological plateaus may be overtaken by unexpected inventions and combinations of technologies over the longer term. From the standpoint of human biological evolution, cultural growth is potentially exponential or nearly exponential over the generations of human evolution, although in particular centuries or millennia there may be fits and starts, plateaus, and also acceleration and stupendous leaps and jumps.

Moreover, from the standpoint of Ogburn's theory, the intellectual content of science is symbolic culture, and the instruments and technological products of science are material culture; thus, the earlier statements that the established knowledge of classical physics does not double every 15-20 years may be evaluated from the standpoint of Ogburn's theory: the symbolic culture of classical physics, or even post-classical physics, does not double every 15-20 years since it is impossible for the established knowledge of classical physics or even post-classical physics to double every 15-20 years; from the standpoint of Ogburn's theory, the instruments of science are part of larger patterns of technological growth in the societies of which they are a part, and thus the instruments and technologies of science usually grow faster than the intellectual content or established knowledge of science. Alfred Louis Kroeber also studied cultural growth in his *Configurations of Cultural Growth* and other works; however, Louis Kroeber recognized that sometimes high-level innovations in cultural patterns jump, leap, or fly ahead of the established symbolic cultural patterns and technological growth of the generation of which the high-level innovations emerge.

It is many times commented that Darwinist theory does not allow 'large mutations' or so-called 'macromutations' across human individuals or individual organisms of other species, since the large mutations across individual organisms are not assimilable by the genetics of breeding populations; however, small or slight heritable variations across human individuals that result in a diversity of behavioral characteristics or branching patterns of behavioral characteristics across human individuals, when expressed in cultural patterns, like written languages (Latin, English, or other languages) or Arabic numerals, may result in spectacular expressions of "progress" in behavioral characteristics and cultural achievements in science, philosophy, religion, technology, music, and the

arts. Prominent examples include the scientific revolutions of Ptolemy, Copernicus, Galileo, or Newton, or the technological revolutions of Watt, Marconi, Edison, Ford, Bill Gates, or Steve Jobs, or the religious "revolutions" that established the major world religions, of Confucius, Buddha, Christ, Muhammed, or Moses. Important cultural achievements, or cultural "progress," or "revolutions," sometimes are not generational: Alfred Louis Kroeber comments that the Chinese language existed for thousands of years before Chinese scholars recognized, when in contact with and translating Buddhist texts from Sanskrit, that the Chinese language had tones; Wittgenstein, Noam Chomsky, and Jorge Luis Borges suggest that ideas about the nature of language remained largely unchanged since the work of St. Augustine; philosopher John Dewey comments that concepts of biological inheritance remained largely derivative of Aristotle's concept of 'pangenesis,' including the work of Darwin and Wallace, until Mendel's conception of particulate units of genetic inheritance; the particulate units of genetic inheritance that Mendel postulated to develop his simple predictive rules on the nature of genetic inheritance were not identified for nearly a century, by Watson and Crick in their model of the double-helical structure of the DNA; early physics retained Aristotle's theory of gravity until Galileo showed Aristotle's conception to be illogical and theory to be empirically wrong.

Generalizing from Ogburn's perspective, scientific theory and mathematics usually "lag" behind incessant or nearly incessant technological growth; however, sometimes, scientific theory jumps, leaps, or flies ahead of established knowledge and even contemporary technology.

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